Geological Survey
of Canada

Current Research
2000-C22

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2000

Natural Resources Canada   Ressources naturelles Canada

Canada

Catalogue No. M44-2000/C22E-IN
ISBN 0-660-18041-3

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Authors' addresses

J.A. Percival *(joperciv@NRCan.gc.ca)*
Continental Geoscience Division
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8

G.M. Stott *(greg.stott@ndm.gov.on.ca)*
Ontario Geological Survey
933 Ramsey Lake Road
Sudbury, Ontario P3E 6B5

Toward a revised stratigraphic and structural framework for the Obonga Lake greenstone belt, Ontario[1]

J.A. Percival and G.M. Stott
Continental Geoscience Division, Ottawa

Percival, J.A. and Stott, G.M., 2000: Toward a revised stratigraphic and structural framework for the Obonga Lake greenstone belt, Ontario; Geological Survey of Canada, Current Research 2000-C22, 8 p. (online; http://www.nrcan.gc.ca/gsc/bookstore)

Abstract: Located on-strike between the Sturgeon–Savant belt of the western Wabigoon Subprovince and Onaman–Tashota belt to the east, the Obonga greenstone belt holds keys to stratigraphic and structural correlation across the central Wabigoon Subprovince. Postulated unconformable relationships between Mesoarchean basement and Neoarchean volcanic cover sequences were found to be tectonic, although geochemistry of volcanic rocks indicates continental contamination. Volcanic and intrusive rocks of the southern assemblage (2734–2726 Ma) are bordered to the north by a south-facing northern assemblage of sedimentary, mafic and felsic volcanic rocks with younger ages, negating simple synformal geometry. Significant east-trending shear zones that bound and occur within the belt range from ductile phyllonite and mylonite zones with dip-slip and strike-slip geometry, to cataclastic dip-slip zones. The Wig Creek conglomerate, containing volcanic and granitic clasts, may be a Timiskaming-type deposit.

Résumé : La ceinture de roches vertes d'Obanga se situe parallèlement à la direction entre la ceinture de Sturgeon–Savant, dans la partie ouest de la Sous-province de Wabigoon, et la ceinture d'Onaman–Tashota, à l'est. Elle permet une corrélation stratigraphique et structurale dans la partie centrale de la Sous-province de Wabigoon. Les relations entre le socle mésoarchéen et les séquences de couverture volcaniques néoarchéennes, qui étaient considérées auparavant comme des relations de discordance, sont maintenant interprétées comme étant tectoniques, bien que la géochimie des roches volcaniques indique qu'il y a eu contamination continentale. Les roches volcaniques et intrusives de l'assemblage sud (de 2734 à 2726 Ma) sont bordées au nord par un assemblage nord de roches sédimentaires et de roches volcaniques mafiques et felsiques plus jeunes, à vergence sud, éliminant ainsi la possibilité d'une géométrie synforme simple. Des zones de cisaillement importantes, à orientation est, qui bordent la ceinture et se rencontrent à l'intérieur de celle-ci, vont de zones ductiles à phyllonite et à mylonite ayant une géométrie de failles normales et de décrochements, à des zones cataclastiques à rejet incliné. Le conglomérat de Wig Creek, qui contient des éléments volcaniques et granitiques, pourrait représenter un dépôt du type témiscamien.

[1] Contribution to Western Superior NATMAP Project

INTRODUCTION

Both continental fragments of Mesoarchean age and Neoarchean volcanosedimentary sequences are present in the western Superior Province of Ontario (Stott, 1997), yet there is no consensus as to how these components were juxtaposed. Field relationships rarely allow distinction between unconformable and tectonic contacts owing to the effects of late intrusions or faults. The Western Superior NATMAP Project is using a multidisciplinary, multi-institutional approach to map the distribution of old crustal blocks and determine the timing of assembly with Neoarchean supracrustal rocks. Results distinguishing continental from oceanic sequences should be useful first-order exploration guides.

Central Wabigoon region

The central Wabigoon region (Thurston and Davis, 1985), containing rocks approaching 3.1 Ga, separates relatively juvenile Neoarchean (2.775–2.70 Ga) volcanic sequences of the western Wabigoon Subprovince (Blackburn et al., 1991; Henry et al., 1998) from 3.05–2.7 Ga volcano-plutonic units of the eastern Wabigoon (Stott et al., 1998; Fig. 1). Located between the Sturgeon–Savant belt on the west and Onaman–Tashota belt on the east, the Obonga Lake greenstone belt hosts a variety of volcanic, sedimentary, and intrusive units representing potential linkages with adjacent belts. Establishing the viability of potential correlations across the Wabigoon Subprovince will provide critical constraints on models of assembly of ca. 3 Ga continental and ca. 2.7 Ga oceanic domains.

Detailed observations of field relationships, complemented by U-Pb geochronology, underpin stratigraphic and structural correlations between the volcanosedimentary sequences of the Wabigoon Subprovince, which are commonly separated by wide tracts dominated by granitoid rocks. Modern stratigraphic frameworks are available for the Sturgeon–Savant greenstone belt (Sanborn-Barrie and Skulski, 1999) and Onaman–Tashota belt (Stott et al. 1998); however, recent geochemical and geochronological studies in the Obonga belt (K.Y. Tomlinson, D.W. Davis, J.A. Percival, D.J. Hughes, and P.C. Thurston, unpub. ms., 1999), are based on maps prepared in the 1960s (Kustra, 1966, 1967a, b; Thurston, 1967, 1968a, b, c, d, e, f), augmented by local more recent observations (e.g. Sage et al., 1974; Cortis et al., 1988; Sage, 1998a; Percival, 1998; Percival et al., 1999). The purpose of this contribution is to synthesize information acquired in a series of transects during the 1997, 1998, and 1999 field seasons, in working toward a modern tectonostratigraphic framework for the Obonga belt. Essential geochronological control has been acquired in collaboration with K.Y. Tomlinson and D. Davis.

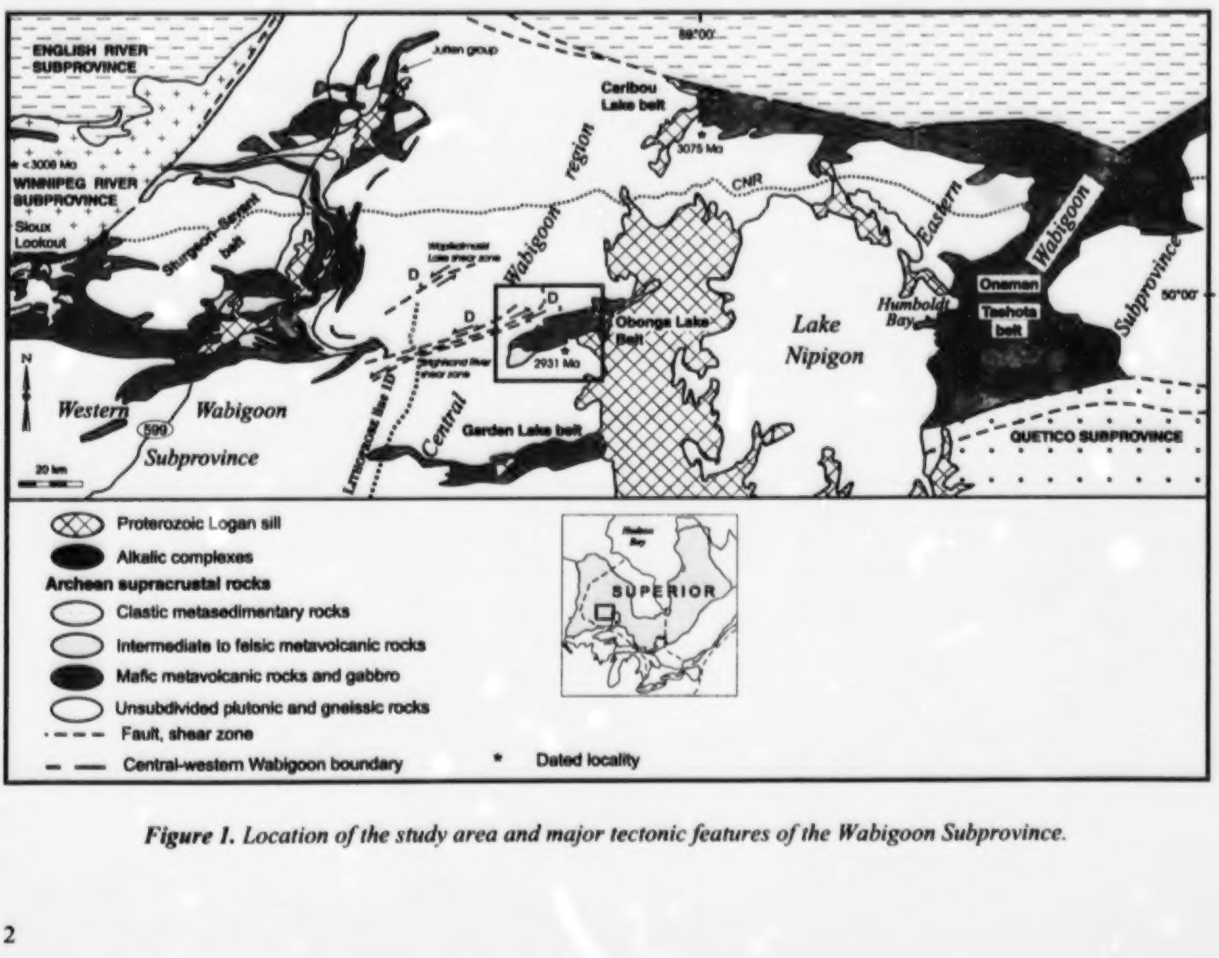

Figure 1. Location of the study area and major tectonic features of the Wabigoon Subprovince.

On the basis of the revised interpretation of the Obonga belt, we examine possible stratigraphic linkages across the central Wabigoon Subprovince.

PREVIOUS MAPPING AND INTERPRETATIONS

The Obonga belt was first described by Kidd (1934), who noted interbedded volcanic (Keewatin series) and sedimentary units, as well as mafic intrusive units and serpentine rocks. Systematic detailed mapping was carried out by Kustra (1966, 1967a, b) and Thurston (1967, 1968a, b, c, d, e, f), who interpreted the belt as a simple synform based on sparse stratigraphic facing indications. Sage (1998a, b) made subsequent observations and compiled the geology of the belt. As part of the Geology of Ontario synthesis, Cortis et al. (1988) revisited the southern Obonga belt, and concluded that mafic volcanic rocks unconformably overlie trondhjemitic basement. A U-Pb zircon age of 2930 Ma on this body, in combination with ages of volcanic rocks in the 2734–2726 Ma range, apparently confirmed the interpretation (D.W. Davis and M. Moore, unpub. report, 1991). Furthermore, negative ε_{Nd} values of some volcanic rocks from the southern part of the belt indicate contamination by old crust (Tomlinson et al., 1998).

The northern margin of the belt was also interpreted as an unconformity, based on the observation that conglomerate units with high-Cr matrices structurally overlie ultramafic rocks to the north (C.R. Kustra, unpub. report interpreted by Sage (1998a)). This relationship was apparently confirmed by the presence of detrital zircons in the 2.92–2.85 Ga range (Tomlinson et al., 1997).

STRATIGRAPHY AND STRUCTURE

Basement-cover relations

Although the presently available geochronology is consistent with the interpretation that supracrustal rocks unconformably overlie crystalline basement, documented unconformities are rare. Our examination of both the northern and southern contacts showed strongly tectonized zones more consistent with fault contacts.

Contacts between various components of the belt are exposed in the Puddy–Chrome lakes area (Fig. 2). Medium-grained biotite tonalite bounds the Puddy Lake serpentinite on the north. Within 100 m of the contact ('A', Fig. 2), tonalite has shear fabrics including an intense, moderately north dipping (30–45°) foliation striking east-southeast, and faint, gently (3–18°) west-plunging crenulation lineation. Dextral transcurrent shear sense was inferred from feldspar sigmoids, extensional shear bands, and local S/C fabrics. Ultramafic rocks south of the contact consist of pods of serpentinite with preserved igneous texture, separated by anastamosing serpentine veins, and appear less strained than adjacent, structurally overlying tonalite. Further south within the Puddy Lake serpentinite body ('B', Fig. 2), two sets of structures are present, 1) an early, moderately north-dipping penetrative grain-shape foliation, cut by 2) steeply dipping, bifurcating, serpentinitic shear zones. The early fabric is concordant to structures at the northern margin of the body, whereas the younger shear zones parallel its steeply north-dipping southern contact.

South of Puddy Lake ('C', Fig. 2), the serpentinite body is bound to the south by mixed metasedimentary and granitic rocks. Medium-grained serpentinite schist is separated by a narrow valley from fine-grained schistose rocks with granitoid lenses, previously described as conglomerate (Kustra, 1967a, b), to the south. Several observations suggest that these rocks are mylonite derived from a granitic protolith. The 20 m wide zone consists of centimetre- to metre-wide panels of fine-grained, flaggy schist, resembling straight-banded ultramylonite, with intense foliation and strong, moderately west-plunging rodding lineation, and intervening panels with sporadic 1–20 cm granodiorite lenses separated by a network of anastomosing, centimetre-scale, fine-grained shear zones. Shear bands within this material demonstrate consistent dextral asymmetry (Percival et al., 1999, Fig. 10). The east-striking, moderately north-dipping, high-strain fabric is transected at a low angle by thin dykes of fine-grained granodiorite, which are affected by a weak, northeast-striking, subvertical cleavage. We refer to this feature as the north margin mylonite zone.

Strain intensity decreases 100 m to the south, where medium-grained granodiorite is riddled with centimetre-scale shear zones and later quartz veins. In metre-scale low-strain lozenges of granodiorite, xenoliths of bedded siltstone are preserved. Granodiorite is inferred to be in intrusive contact with fine-grained siltstone units to the south, which contain sills of gabbro and granodiorite.

Tectonite zones are present elsewhere along the northern margin of the belt. South of Wig Creek ('D', Fig. 2), the northern belt margin has a ductile shear component and broad cataclastic overprint (Fig. 11, 12, Percival et al., 1999).

Unconformable relationships have also been inferred at the southern margin of the belt. South of Silk Lake ('E', Fig. 2), Cortis et al. (1988) observed a pink granitic phase, interpreted as regolithic trondhjemite, beneath an unconformable contact with volcanic rocks. The pink phase yielded a U-Pb zircon age of 2930 Ma (D.W. Davis and M. Moore, unpub. report, 1991). Our observations at this locality lead to a different interpretation. The oldest rock present in this outcrop area is a medium-grained homogeneous, foliated, quartz porphyritic trondhjemite. It is cut by intrusive dykes and masses of fine-grained, pink, aplitic granodiorite (Fig. 3), which is the phase sampled by Cortis et al. (1988) for geochronology. The aplitic phase is in turn transected by two generations of mafic dykes, an older set of straight-walled, medium-grained gabbro dykes with preserved chill margins and weak internal foliation, and a younger set of fine-grained mafic to ultramafic dykes and sills. A sill of the latter material with a chilled southern contact and making up a north-facing cliff face, was interpreted by Cortis et al. (1988) as the basal unit of the Obonga belt. Granodiorite occurs a few metres to the north, where a "pelitic conglomerate bed" described by

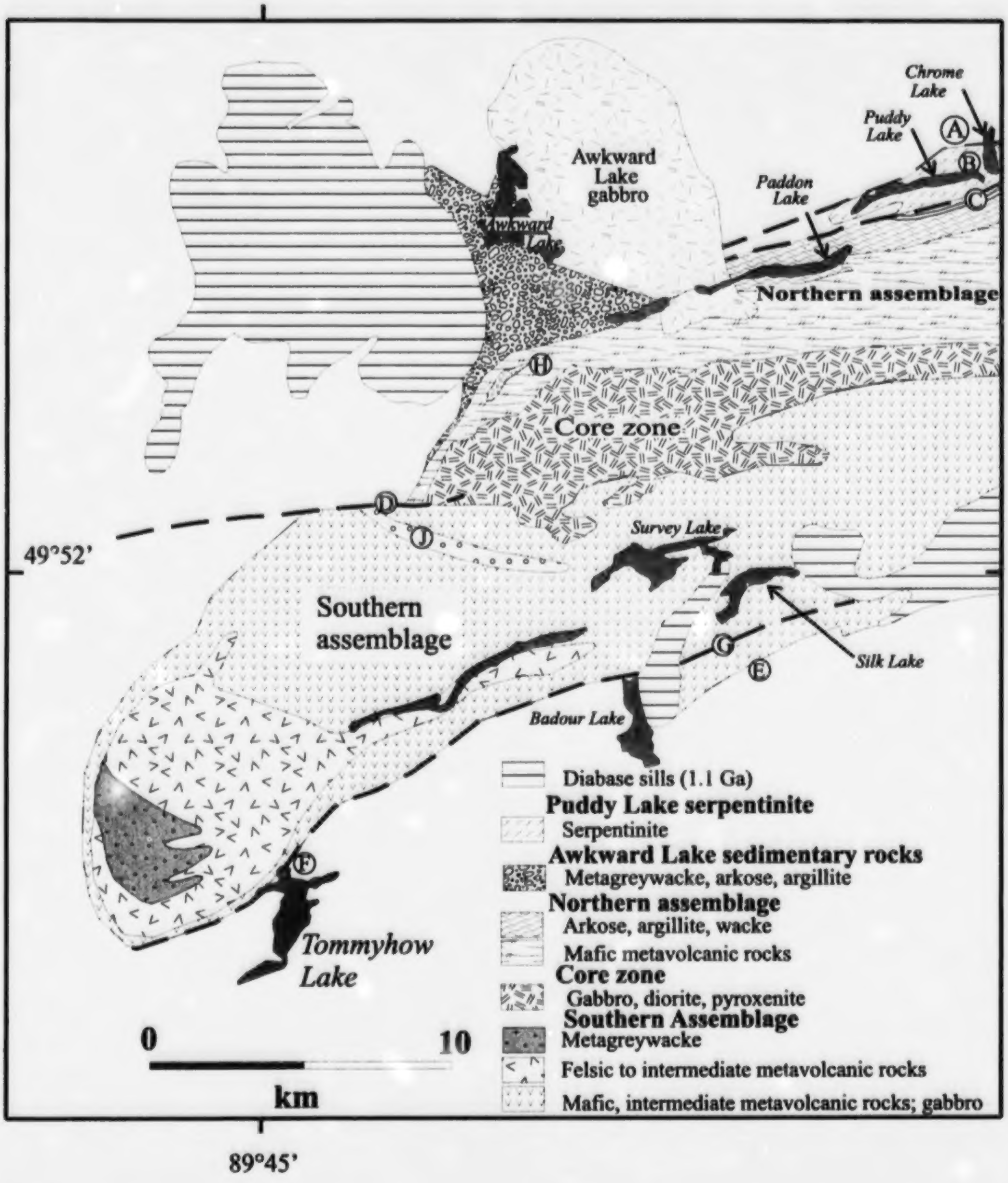

Figure 2. *Generalized geological map showing main lithological packages and major tectonic elements of the Obonga belt (*modified after *Sage, 1998a). Specific locations referred to in the text include: A = northern contact of the Puddy Lake serpentinite; B = Puddy Lake serpentinite; C = north margin mylonite zone; D = cataclastic zone in the Wig Creek area; E = unconformity reported by Cortis et al. (1988); F = southern volcanic contact in northern Tommyhow Lake; G = ductile shear zone in the Silk Lake area; H = mafic-ultramafic intrusion cutting sedimentary rocks younger than 2724 Ma in the northern assemblage; J = Wig Creek conglomerate.*

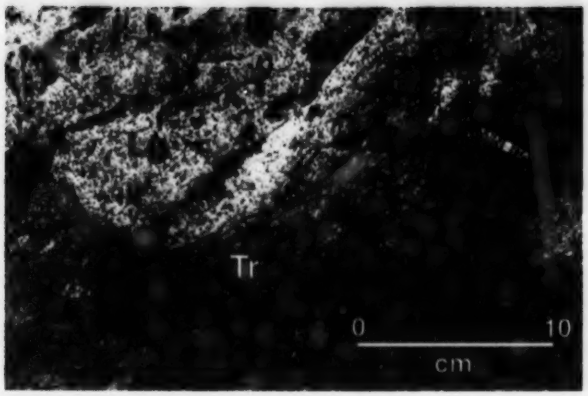

Figure 3. Dyke of fine-grained pink granodioritic aplite (Lg) cutting foliated trondhjemite (Tr).

Cortis et al. (1988) is a 60 cm wide breccia zone containing angular fragments of vein quartz and granite in a chlorite-carbonate-rich matrix. It lies along the contact between a gabbro unit to the north and pink granodiorite to the south and appears to be an intrusive breccia made up of granite fragments injected by gabbro and subsequently altered, rather than a conglomerate bed. A 200 m wide exposure gap to the north separates the outcrop area from metavolcanic rocks and a significant volume of gabbro that extends to Silk Lake.

To the west, the southern contact of the belt is exposed in northern Tommyhow Lake ('F', Fig. 2). Granitoid rocks to the south are medium-grained, homogeneous, foliated trondhjemite cut locally by two sets of mafic dykes. Strain distribution is markedly asymmetric adjacent to the contact, foliation in trondhjemite is pronounced in an approximately 100 m wide zone immediately south of the contact, whereas metavolcanic rocks to the north have rarely preserved primary features, intense foliation and strong downdip lineation in a 3 km wide zone. The immediate contact zone is a steeply dipping, 10 m wide ductile shear zone with downdip lineation and consistent south-side-up movement sense demonstrated by extensional shear band geometry and small fold asymmetry.

Southern assemblage

The Obonga belt has been divided into northern and southern assemblages, separated by a core gabbro zone (Fig. 2; Tomlinson et al., 1996; Sage, 1998a). The southern assemblage consists of mafic and felsic metavolcanic rocks with variably preserved primary structures. Mafic rocks include pillow basalt, mafic schist, and abundant gabbro sills, including glomeroporphyritic varieties, whereas felsic rocks are mainly massive to pyroclastic dacite, and quartz-feldspar porphyry of probable intrusive origin. Unequivocal facing directions are rare in pillowed sequences owing to generally high-strain levels, but indicate consistent northward younging.

A ductile, greenschist-facies shear zone extends northeastward from the shear zone at the southern volcanic contact in northern Tommyhow Lake (Thurston, 1968c, d). Where observed in mafic rocks south of Silk Lake ('G', Fig. 2), it consists of fine-grained chlorite schist, derived from basaltic protoliths, contains abundant dismembered quartz veins, and possesses a strong, steeply dipping foliation and downdip lineation. Sigmoidal foliation fish indicate south-side-up displacement, consistent with observations at Tommyhow Lake.

Two geochemical types have been distinguished in the southern assemblage on the basis of trace-element and isotopic characteristics (Tomlinson et al., 1999), 1) mafic rocks with flat multi-element profiles and depleted-mantle-like Nd signatures; and 2) mafic and felsic rocks with LREE- and thorium-enriched profiles, negative Nb anomalies and negative e_{Nd} values. Felsic rocks have yielded U-Pb zircon ages in the range 2734–2726 Ma (Tomlinson et al., 1998). These geochemical subdivisions are not evident in the field and thus the relationship of the geochemical suites is cryptic.

Core zone

The core zone consists of mafic intrusive rocks including gabbro, diorite, pyroxenite, peridotite, and serpentinized equivalents (Sage, 1998a). Phase layering is present locally in gabbro, suggesting that the various components may be related through fractionation, although the possibility of multiple intrusive bodies cannot be ruled out. A pegmatitic gabbro from the northern part of the core zone contains sparse zircons that yielded a U-Pb age of 2733 ± 7 Ma (Tomlinson et al., 1999). The age for the core zone gabbro, in combination with the presence of abundant gabbroic bodies in the 2734–2726 Ma southern assemblage, suggests that the two are related. However, in detail, the age of the core zone is inconsistent with the homoclinal northward facing of the southern sequence and suggests that the structure may be more complex.

Northern assemblage

Several distinct volcanic, sedimentary, and intrusive bodies make up the northern assemblage. The northernmost part comprises the Awkward Lake sedimentary unit (Fig. 2), consisting of wacke, arkose, argillite, and rare matrix-supported conglomerate with granitic clasts. Although these rocks structurally underlie a mafic volcanic sequence to the south, their internal structure is complex, displaying refolded folds, dismembered beds, and strong transposition fabrics, to the extent that no consistent facing direction is evident. In locations where foliation is relatively weak, beds still display significant dismemberment (Fig. 4) suggesting the possibility of early, (?soft-sediment) deformation. These structures resemble broken formations found in Phanerozoic trench environments (Hamilton, 1979, Fig. 41), although without detailed analysis, it is difficult to rule out strain partitioning into relatively incompetent sedimentary units as the cause of these complex structures. Local andalusite in argillite indicates metamorphism to the lower amphibolite facies. This unit appears continuous with sedimentary rocks with moderately

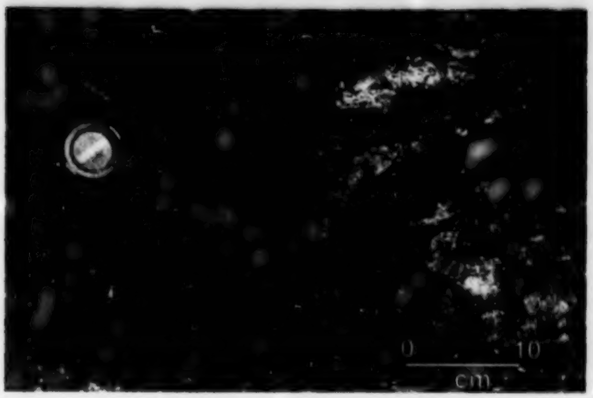

Figure 4. Dismembered beds in the Awkward Lake sedimentary unit.

preserved primary structures to the east, south of Paddon and Puddy lakes (Fig. 2). There, sedimentary units include siltstone, wacke, argillite, and gritty arkose with southward-younging indicators, and are associated with tuffaceous felsic units and minor iron-formation. Gabbro sills make up a small proportion of the sequence. A 100 m thick rhyolite unit within the sediment-dominated package yielded a U-Pb zircon age of 2703 Ma (Tomlinson et al., 1999).

Structurally above the sedimentary unit and separated by a narrow brittle-ductile fault zone (Percival et al., 1999) is a mafic volcanic package dominated by pillow basalt units and gabbro sills. Both have alteration zones of epidote-albite-quartz±tourmaline that are abundant in pillow selvages and flow-top breccia units in volcanic rocks and in shear zones in gabbro (Fig. 4, Percival et al., 1999). Facing indications from pillow criteria and flow tops are consistently south. Geochemically, these rocks have sloping multi-element profiles with no depletion in high field-strength elements and positive ε_{Nd} values, suggesting derivation from depleted mantle and possible plume sources (Tomlinson et al., 1998).

A thin unit of metasedimentary rocks occurs within the volcanic sequence ('H', Fig. 2). The less than 20 m thick package includes quartz-rich sandstone, wacke, argillite, and sulphide-facies iron-formation. Primary structures including graded bedding, channel scours, and ripple marks suggest concordance with bedding in adjacent volcanic rocks and indicate overall southward younging. Detrital zircons from sandstone include populations at 2729 Ma and 2724 Ma (Tomlinson et al., 1999), providing a maximum age for the sedimentary unit, and by inference, overlying volcanic rocks. The base of the sedimentary package is intruded by a 30 m thick layered sill comprising gabbro, pyroxenite, peridotite, and altered equivalents. By inference, the sill is also less than 2724 Ma and therefore not correlative with mafic-ultramafic rocks of the core zone intrusion (ca. 2733 Ma).

A unit of coarse conglomerate with minor gritty sandstone is present in the Wig Creek area in the northwestern part of the belt ('J', Fig. 2). Cobble- to boulder-sized clasts include tonalite, granodiorite, granite, gabbro, basalt, feldspar porphyry, and andesite-dacite. Where exposed, contacts with volcanic and granitoid rocks are tectonic. The conglomeratic unit has not been dated, however on the basis of field relationships, particularly the presence of granite clasts, we infer that it represents a 'Timiskaming-type' sequence, and may be the youngest component of the belt.

OUTSTANDING PROBLEMS

The Obonga belt was last mapped systematically in the 1960s. Our scattered observations indicate several outstanding problems that could be addressed through remapping. However, it is worth noting that forest fires and regrowth since the 1960s have created thick bush over large areas, including some tracts of blow-down that are virtually impassable.

Basement-cover relationships

Although an unconformable relationship could not be substantiated for the southern margin of the belt, certain observations require explanation. Rocks older than 2.9 Ga are present south of the Obonga belt, in inferred fault contact, and the original stratigraphic relationship is undefined. The mafic and ultramafic dykes that cut trondhjemite and granodiorite could have fed some volcanic units, particularly those of the southern sequence with negative ε_{Nd} values. Alternatively, the dykes are late tectonic or ultramafic intrusions younger than 2724 Ma, similar to those in the northern part of the belt. In the north, potential basement units have not been identified and contacts between external granitoid and supracrustal rocks are tectonic.

Tectonostratigraphy of the Obonga belt

Based on available geochronology, rocks of the southern assemblage are the oldest of the belt (2734–2726 Ma). Gabbro of the core zone is equivalent in age to the older supracrustal units and probably related, based on the presence of abundant gabbroic sills in the southern assemblage. This relationship contradicts the interpretation of a simple homocline for the southern assemblage. Some volcanic and sedimentary rocks of the northern assemblage are younger than 2724 Ma, and others as young as 2703 Ma. Previous interpretations of the gross-scale structure of the Obonga belt as a simple syncline, cored by the core zone intrusion, require re-evaluation in light of the stratigraphically mismatched homoclinal panels on opposing limbs of the purported fold. Current observations require a fundamental tectonic break between the south-facing panel of less than 2724 Ma rocks of northern assemblage and 2734–2726 Ma rocks of the southern assemblage and associated core zone intrusion.

Age and tectonic significance of the Awkward Lake metasedimentary rocks

Located structurally beneath pillow basalt within the northern assemblage, this complexly deformed package could represent an older supracrustal component with structures

predating 2.74 Ga. Conversely, it could correlate with younger units and require a more complex structural interpretation. In particular, if the widespread dismemberment of beds in this unit can be shown to be an early (soft-sediment) tectonic feature, the unit could mark an accretionary boundary, as has been inferred for the Savant sedimentary group to the west (Sanborn-Barrie and Skulski, 1999).

Significance of the Wig Creek conglomerate

This unit forms a linear map pattern that trends southeastwards, obliquely across the dominant stratigraphic grain of the southern assemblage. Consequently it resembles an unconformable, younger package similar to Timiskaming-type sequences observed in other greenstone belts such as Shebandowan in the Wawa Subprovince. We speculate that the orientation of this linear assemblage might correspond to the formation of a narrow pull-apart basin induced by northwest-southeast wrenching of the Obonga belt coeval with dextral shearing along the north and south margins of the belt.

REGIONAL CORRELATIONS

Based on the observed relationships and available geochronology, we explore possible correlations among the Obonga, Sturgeon–Savant, and Onaman–Tashota belts. Similarities are evident in both stratigraphy and structure between parts of the Obonga belt and the Onaman–Tashota belt east of Lake Nipigon (Stott and Straub, 1998). Volcanic packages of ca. 2730 Ma in both belts (southern assemblage in Obonga; Onaman–Metcalfe block in Onaman–Tashota) are dominantly pillow basalt, with subsidiary felsic pyroclastic units and abundant gabbroic sills. The Conglomerate Lake sedimentary sequence in the Onaman–Tashota belt, containing 2707 Ma detrital zircons (Stott et al., 1998), has a similar clast population and sedimentary characteristics to the undated Wig Creek conglomerate. The Humboldt Bay high-strain zone of the Onaman–Tashota belt extends westward into the central Wabigoon Subprovince, where it could correspond to a number of structures within the Obonga belt, most likely to the north margin mylonite zone, on the basis of common flaggy mylonite units forming a steeply dipping straight zone.

To the west, the Sturgeon–Savant belt has several stratigraphic packages of equivalent age to those of the Obonga belt. Although the South Sturgeon sequence (2735–2733 Ma), which contains massive sulphide mineralization, is of similar age to the southern assemblage of the Obonga belt, it formed in a probable island-arc setting (Skulski et al., 1998; Sanborn-Barrie and Skulski, 1999), in contrast to the continental influence demonstrated by some southern assemblage rocks (Tomlinson et al., 1998). Units of the less than 2704 Ma Savant sedimentary group, interpreted as a foredeep clastic succession, extend into the easternmost Sturgeon Lake belt (Sanborn-Barrie and Skulski, 1999) and may be age equivalent to undated sandstone-siltstone-argillite units associated with 2703 Ma rhyolite in the northern assemblage. Similarly, units younger than 2724 Ma in the northern assemblage appear to lie on strike with dacitic units and associated sedimentary rocks of comparable age east of Lake Nipigon in the central Onaman–Tashota greenstone belt — the less than 2713 Ma Humboldt Bay sequence and 2722 Ma Metcalfe–Lake Ste. Marie sequence (Stott and Davis 1999).

ACKNOWLEDGMENTS

We thank Kirsty Tomlinson for sharing geochronological and geochemical data, for visits to the field, and for helpful comments on an earlier version of the manuscript. West Caribou Air Services (Savant Lake, 1998) and Huron Air (Armstrong, 1999) provided efficient float-plane service. Marc St-Onge provided helpful comments on the manuscript.

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